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EFFECT OF BORAX IN FERTILIZER ON THE GROWTH AND YIELD OF POTATOES.

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PURPOSE OF THE INVESTIGATIONS.

Injury to field crops through the use of fertilizers containing borax was first observed in Indiana in 1917, and a report by Conner (*1*)[2] appeared in 1918.

So far as is known no reported authentic case of borax injury again occurred until 1919, when ample proof of the poisonous action of this compound was afforded. During the growing season of 1919 injury to a number of important crops by borax, notably potatoes, cotton, and tobacco, was observed, and a number of publications (*2, 3, 4, 5, 6*) on this subject were subsequently issued.

The Bureau of Plant Industry, as a result of reports from various sections, conducted an investigational survey in the field in 1919 to determine the severity and extent of the injury, with special reference to potatoes and cotton. The survey was based in part on experimental plat work with fertilizers containing borax and in part on actual observation in affected fields. As a result of these investigations, as well as those by others, it was found that borax caused the trouble. It was deemed essential, however, to conduct well-controlled field tests during the season of 1920 for the purpose of studying

[1] Experiments conducted during the season of 1920 on the Aroostook farm of the Maine Agricultural Experiment Station, at Presque Isle, Me.

[2] Serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

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certain matters, namely: (1) The effect of different rates of application of borax per acre when mixed with fertilizer, as compared with equal quantities of fertilizer to which borax was not added, upon the growth and yield of a number of crop plants; (2) the influence of th time and method of application of a fertilizer mixture containing borax in varying quantities; and (3) the influence of rainfall and soil type on the extent of borax injury. Accordingly, cooperative experimental field work was conducted at Presque Isle, Me., on Caribou loam, with potatoes; at New Bunswick, N. J., on Sassafras loam, with potatoes and corn; at the Arlington Experimental Farm, Va., on Arlington clay loam with potatoes, corn, cotton, Lima beans, and string beans; and at Muscle Shoals, Ala., on Colbert and Decatur loams with corn and cotton.

Blair and Brown (*7*) presented an article in Soil Science giving the results obtained at New Brunswick, N. J., with potatoes and corn. A report by Skinner and Allison (*9*) on the results obtained with cotton at Muscle Shoals, Ala., and at the Arlington Experimental Farm, Va., is shortly to appear. The present bulletin embodies the results obtained at Presque Isle, Me., with potatoes, when grown on Caribou loam (*8*, p. 6), the important soil type of that region.

PLAN OF THE EXPERIMENTS.

The experiments as carried out in Maine were similar to those at the other field stations in that the same fertilizer was used and the rates of application of borax per acre were the same, the only difference being that the quantity of fertilizer applied was 2,000 pounds per acre in Maine and 1,500 pounds per acre in New Jersey.

What was actually done was to make up a 4–8–4 fertilizer mixture from nitrate of soda, sulphate of ammonia, cottonseed meal, acid phosphate, and muriate of potash, the ammonia being derived equally from the three nitrogen sources. To this 4–8–4 mixture were added varying quantities of borax, so that anhydrous borax was applied at the following rates per acre: 1, 2, 3, 4, 5, 10, 20, 30, 50, 100, 200, and 400 pounds. In order properly to compare the influence of the borax, five control plats, to which fertilizer alone was added, were included. To simplify the field work, the plat numbers were made to correspond to the rate of application of borax per acre. That is, plat 1 received 1 pound of borax per acre, plat 10 received 10 pounds of borax per acre, and plat 400 received 400 pounds of borax per acre. To each plat, irrespective of the quantity of borax added, the same quantity of fertilizer was applied. The land used for the experiment was divided crosswise into three equal sections, in order to provide for the following methods of applying the fertilizer: To the plats in section 1 the normal fertilizer and the fertilizer-borax mixtures were applied in the furrow on May 31,

mixed with the soil, and allowed to remain until June 5; on June 5 the normal fertilizer and fertilizer-borax mixtures were applied to sections 2 and 3; in section 2, the mixtures were applied as in section 1; while in section 3 they were sown broadcast and well raked into the soil before planting. All three sections were then planted on June 5.

RESULTS OF THE EXPERIMENTS.

On July 5, one month after planting, notes on the experiments were taken by Dr. Donald Folsom, of the Maine Agricultural Experiment Station. The notes and observations made by him disclose the following: (1) The average number of plants above ground in the control plats in all sections was 343. These rows received fertilizer at the rate of 1 ton per acre, but no borax. (2) The average number of plants above ground in all sections of the 12 fertilizer-borax plats was only 216. These 12 plats received borax varying from 1 to 400 pounds per acre. (3) As the quantity of borax increased there was a marked falling off in the number of plants above ground, until with an application rate of 400 pounds per acre only 12 plants appeared. The application of borax at the rate of 10 pounds per acre materially reduced the number of plants above ground, there being 284 plants as compared with the 343 of the control plats. The plats receiving borax at the rate of 5 pounds per acre had 306 plants. The 20-pound application showed 205 plants; the 30-pound application, 139 plants; the 50-pound application, 116 plants; the 100-pound application, 38 plants; the 200-pound application, 18 plants; and, as previously stated, the 400-pound application only 12 plants.

On August 5 the writer inspected the borax experiments for the purpose of taking notes, obtaining photographic records, etc. At this time the stand, differences in growth, appearance of vines, etc., were definitely established. The main fact disclosed was that section 2, where the fertilizer-borax mixtures were applied in the furrow at the time of planting, looked much more seriously affected than section 1, where the fertilizer-borax mixtures were applied in the furrow and stood awhile before planting. Section 3, however, in which the fertilizer-borax mixtures were sown broadcast, showed injury, not so marked as in section 2, but the plants were uniformly below the standard established by the plants in section 1. Apparently broadcasting was effective in curtailing the injury by borax to a considerable extent, but this good effect was offset by the fact that the fertilizer itself was not as available to the plants, especially where small quantities of borax were applied, as it would have been if applied in the furrow, which is the usual custom.

Applying the fertilizer in the furrow, followed by immediate planting, as in section 2, is the usual practice in Aroostook County, so that

the degree of injury occurring in this section as well as curtailment of yield would be of greater practical significance than in sections 1 and 3. The accompanying illustrations [3] show very well the type and degree of injury found, especially the effect of applying small quantities of borax. (Pl. I.) As the quantity of borax increased there was a marked falling off in the number of plants on a plat (Pl. II) as well as a reduction in the size of the plants (Pl. III, Figs. 1 and 2, compared with a normal plant in Fig. 3). A great many apparently empty hills when dug into disclosed seed pieces affected to the extent shown in Plate IV, Figure 1. The greatest degree of injury resulted from the use of the larger quantities of borax, namely, 100, 200, and 400 pounds per acre (Pl. IV, Fig. 2).

During the investigational survey in Maine in 1919 the quantity of anhydrous borax found in commercial fertilizers collected ranged from 0.73 to 2.3 per cent. In view of the fact that 2,000 pounds represents the usual quantity of fertilizer applied per acre, it is evident that the borax applied ranged from 14.6 to 46 pounds. The type of field injury shown in 1919 was similar to that found with the 20, 30, and 50 pound applications in the borax experiment of 1920, thereby serving to substantiate the previous findings. Some of the injurious effects noted in both seasons were as follows. (1) Failure of seed to germinate; (2) dying back of underground sprouts; (3) bleaching of foliage, or, if the plant was not seriously injured, a marginal yellowing of the leaflets; (4) reduction in size of plants below normal; and (5) a reduction in yield.

On September 9, the plats were harvested and the weights of the potatoes, by plats for the three sections, were recorded (Table 1). The results are presented graphically in Figure 1.

In section 1, where borax was applied in the furrow, injury occurred from the 10-pound application of borax and became progressively worse. It will be noted, however, that the degree of injury was less than in section 2, where the borax was applied in the furrow and planting was done immediately. The application of 1, 2, and 3 pounds of borax per acre apparently stimulated plant growth, and the yields were increased.

In section 2 the injury was apparently produced with as small quantities of borax as 3 or 4 pounds per acre, certainly with 5 pounds; and the injury with 10 pounds and more was great.

One of the significant features of section 2 is the effect shown on the yield by the 10, 20, 30, and 50 pound applications of borax, as this was practically the range found during the investigational survey made in 1919.

[3] The writer is indebted to Dr. C. F. Clark, of the Office of Horticultural and Pomological Investigations for his cooperation in obtaining photographic records.

FIG. 1.—EFFECT ON POTATOES OF 10-POUND, 5-POUND, AND 4-POUND APPLICATIONS OF BORAX PER ACRE.

FIG. 2.—EFFECT ON POTATOES OF 3-POUND, 2-POUND, AND 1-POUND APPLICATIONS OF BORAX PER ACRE.

Control rows on right and left. No injury shown by such small quantities of borax.

FIG. 1.—EFFECT ON POTATOES OF 20-POUND, CONTROL, AND 10-POUND APPLICATIONS OF BORAX PER ACRE.

FIG. 2.—EFFECT ON POTATOES OF 50-POUND, 30-POUND, AND 20-POUND APPLICATIONS OF BORAX PER ACRE.

Control rows on right and left.

FIG. 1.—INDIVIDUAL POTATO PLANT. SMALL AND BADLY INJURED FROM AN APPLICATION OF 20 POUNDS OF BORAX PER ACRE.

FIG. 2.—INDIVIDUAL POTATO PLANT FROM SAME ROW AS THAT SHOWN IN FIGURE 1, BUT SHOWING SOME RECOVERY.

FIG. 3.—INDIVIDUAL POTATO PLANT FROM A CONTROL PLAT WHICH RECEIVED NO BORAX.

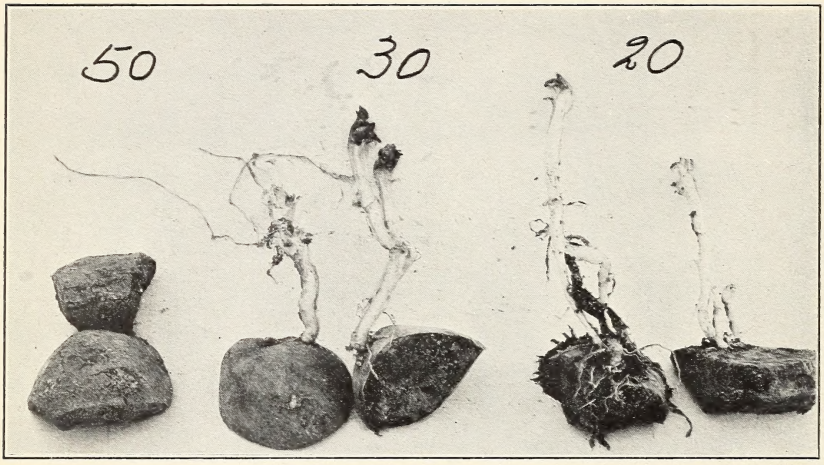

FIG. 1.—INJURY TO POTATO SEED PIECES FROM APPLICATION OF 50, 30, AND 20 POUNDS OF BORAX PER ACRE.

Appearance two months after planting.

FIG. 2.—EFFECT ON POTATOES OF 400-POUND, 200-POUND, AND 100-POUND APPLICATIONS OF BORAX PER ACRE.

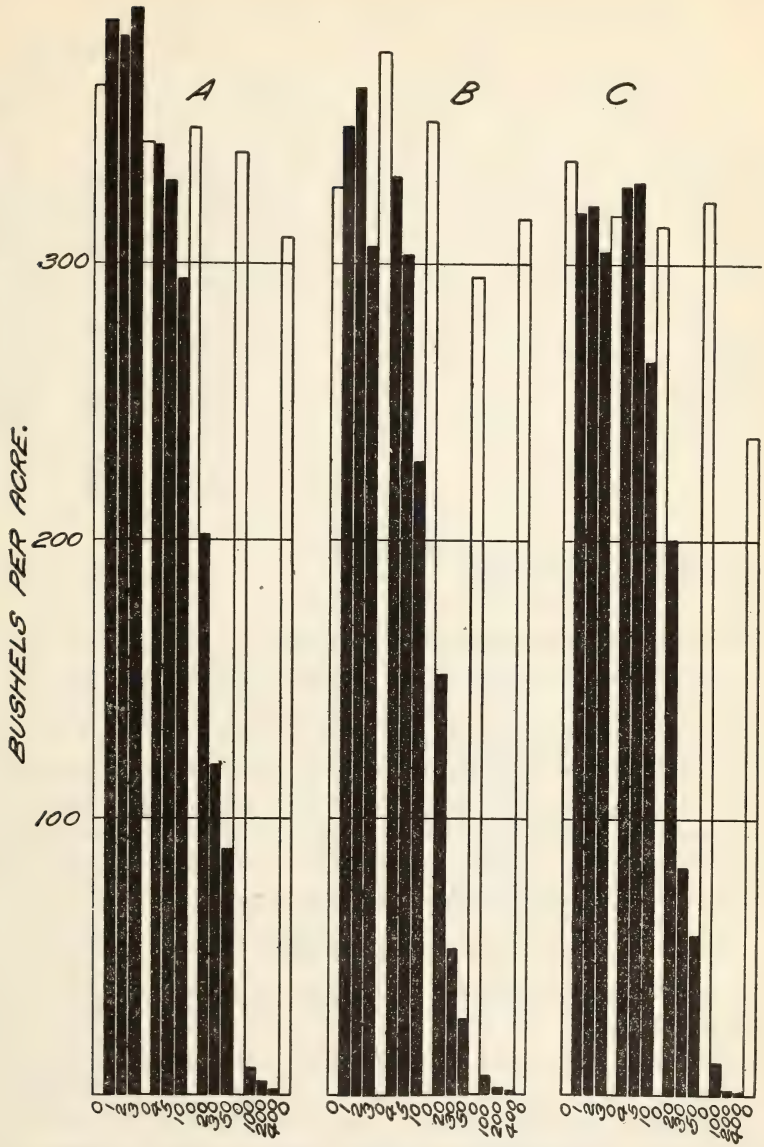

FIG. 1.—Diagram showing the yield of potatoes in experiments with borax at Presque Isle, Me., in 1920. The figures at the base of each column denote the number of pounds of borax applied per acre. The controls, designated by 0, received only a complete commercial fertilizer, applied at the rate of 2,000 pounds per acre. The borax treatments were prepared by mixing the borax with the same quantity of commercial fertilizer that was used in the controls. Application of fertilizer: *A*, In the furrow one week before the time of planting; *B*, in the furrow at the time of planting; *C*, broadcast over the rows at the time of planting.

TABLE 1.—*Yield of potatoes in borax experiment at Presque Isle, Me., in 1920.*

Quantity of borax applied per acre.	Yield per acre (pounds).		
	Section 1.[a]	Section 2.[b]	Section 3.[c]
0 (Control 1)	21,760	19,600	20,240
1 pound	23,200	20,960	19,120
2 pounds	22,880	21,760	19,440
3 pounds	23,440	18,320	18,240
0 (Control 2)	20,560	22,560	19,040
4 pounds	20,480	19,840	19,680
5 pounds	19,720	18,160	19,760
10 pounds	17,600	13,680	15,840
0 (Control 3)	20,880	21,040	18,800
20 pounds	12,080	9,040	12,000
30 pounds	7,120	3,120	4,880
50 pounds	5,280	1,600	3,400
0 (Control 4)	20,320	17,680	19,300
100 pounds	560	320	640
200 pounds	240	80	160
400 pounds	80	[d] 40	80
0 (Control 5)	18,560	18,960	14,240

[a] Fertilizer applied in the furrow about one week before planting.
[b] Fertilizer applied in the furrow planting.
[c] Fertilizer applied broadcast at planting.
[d] All culls.

In section 3 the general trend of the results is similar to that in sections 1 and 2, the first sign of injury occurring, however, with the 10-pound application. In this section the method of applying the fertilizer-borax mixtures apparently depressed the yield of the last contral as the yield dropped off considerably. In this connection, in view of the fact that single rows were employed in the borax experiments, it would seem that broadcasting a fertilizer-borax mixture containing such a large quantity of borax might easily tend to influence the yield of the adjacent control row.

RAINFALL RECORD.

The daily rainfall record for the months of June, July, and August is given in Table 2.

The rainfall, subsequent to planting on June 5, was well distributed during the remainder of that month, at least until June 29, on which date 1.09 inches fell, followed by 1.01 inches on June 30. It would seem that the rain, which fell between June 5 and June 29—a somewhat critical period in the early life of the potato plant—was sufficient to keep the soil in good condition without much chance of any great leaching of the borax to lower soil zones.

TABLE 2.—*Precipitation at Presque Isle, Me., for June, July, and August, 1920.*

Day.	Rainfall record (inches).			Day.	Rainfall record (inches).		
	June.	July.	August.		June.	July.	August.
1		0.45	0.17	17			
2	0.13			18		0.03	
3	.50	.37	.63	19	0.20	.42	
4		.43		20		.05	
5		1.10		21	.06		
6				22	.57		0.23
7	.73	.11		23	1.02	.06	1.32
8		1.00		24	.10	.03	
9				25	.12	.02	
10			.43	26			.01
11	.49		.12	27	.03		
12			.46	28			
13		.04		29	1.09		
14			.01	30	1.01	.08	.08
15			.01	31			.15
16	.04	.09					

SUMMARY.

This bulletin presents the results of borax experiments conducted on Caribou loam, the principal soil type in Aroostook County, Me. Injury definitely occurred with an application as low as 5 pounds of borax per acre, when put in the furrow and when the planting was done immediately, which is the method customarily followed in this section of Maine. The other methods of applying the fertilizer, broadcasting at the time of planting and applying in the furrow some time before planting, did not show injury in as low concentrations of borax as showed injury when the fertilizer-borax mixtures were applied in the furrow at the time of planting. As the quantity of borax was increased the injury in all cases became progressively worse, until, with the larger quantities of borax per acre, great injury ensued.

The moderate and fairly regular rainfall during the month of June was not sufficient to carry the borax out of the reach of the growing plant, so that no alleviation of the injurious action was noticeable.

The types of injury observed in the commercial fields during 1919 were similar to those found in the borax experiments of 1920. Some of the reactions with borax, observed in both seasons, were as follows: Failure of the seed piece to germinate, the killing of sprouts, the absence of roots at seed pieces, general weakness of plants which came through the ground, bleaching of the foliage (or at least a marginal yellowing of the leaf), a poor stand, and low yields.

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